ACME
Accelerated Climate Modeling for Energy

Coupling for ESM: The integrated Earth System Model (iESM)

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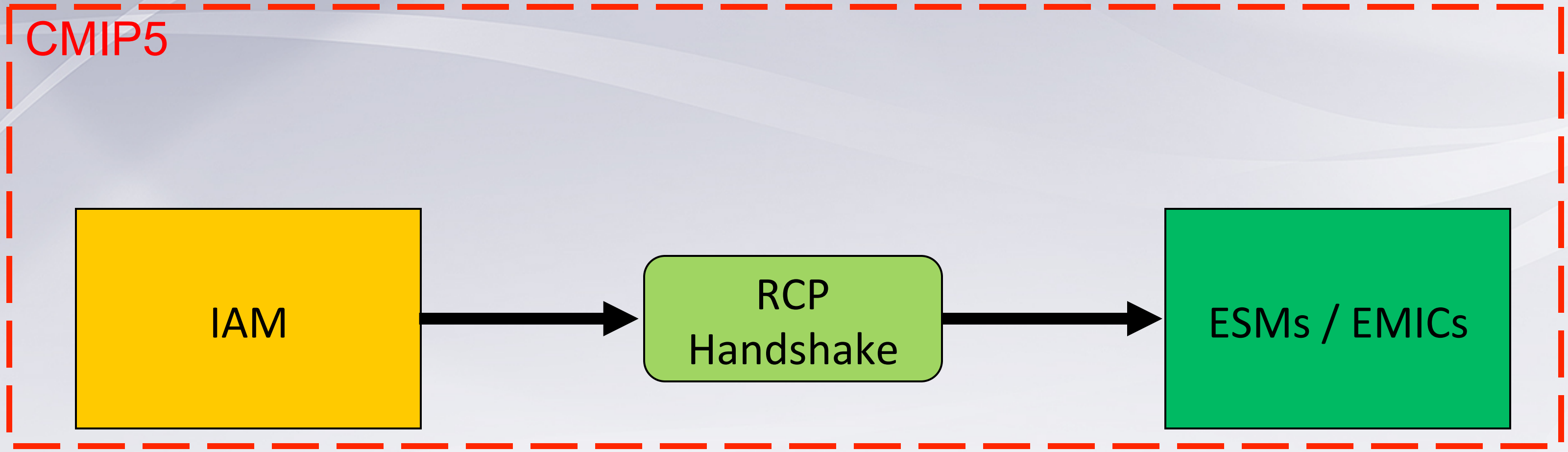
U.S. DEPARTMENT OF ENERGY

Three major objectives of iESM project

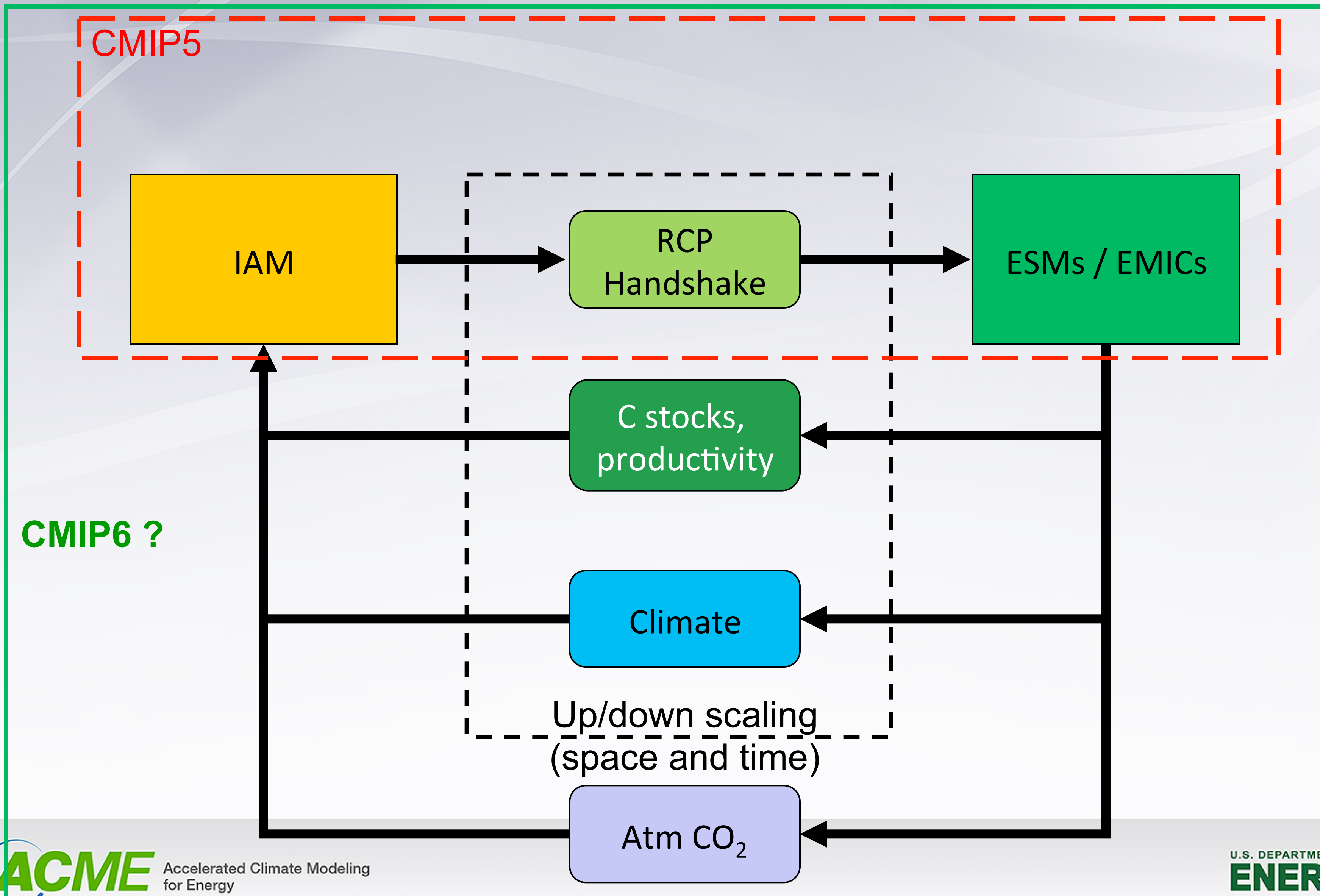
- **Create a first generation integrated Earth System Model (iESM)** with both the human components of an IAM and a physical ESM
- Develop linkages within the iESM and apply the model to improve **our knowledge of coupled physical, ecological, and human system**
- Add hydrology and water demand, allocation, and availability to IA.



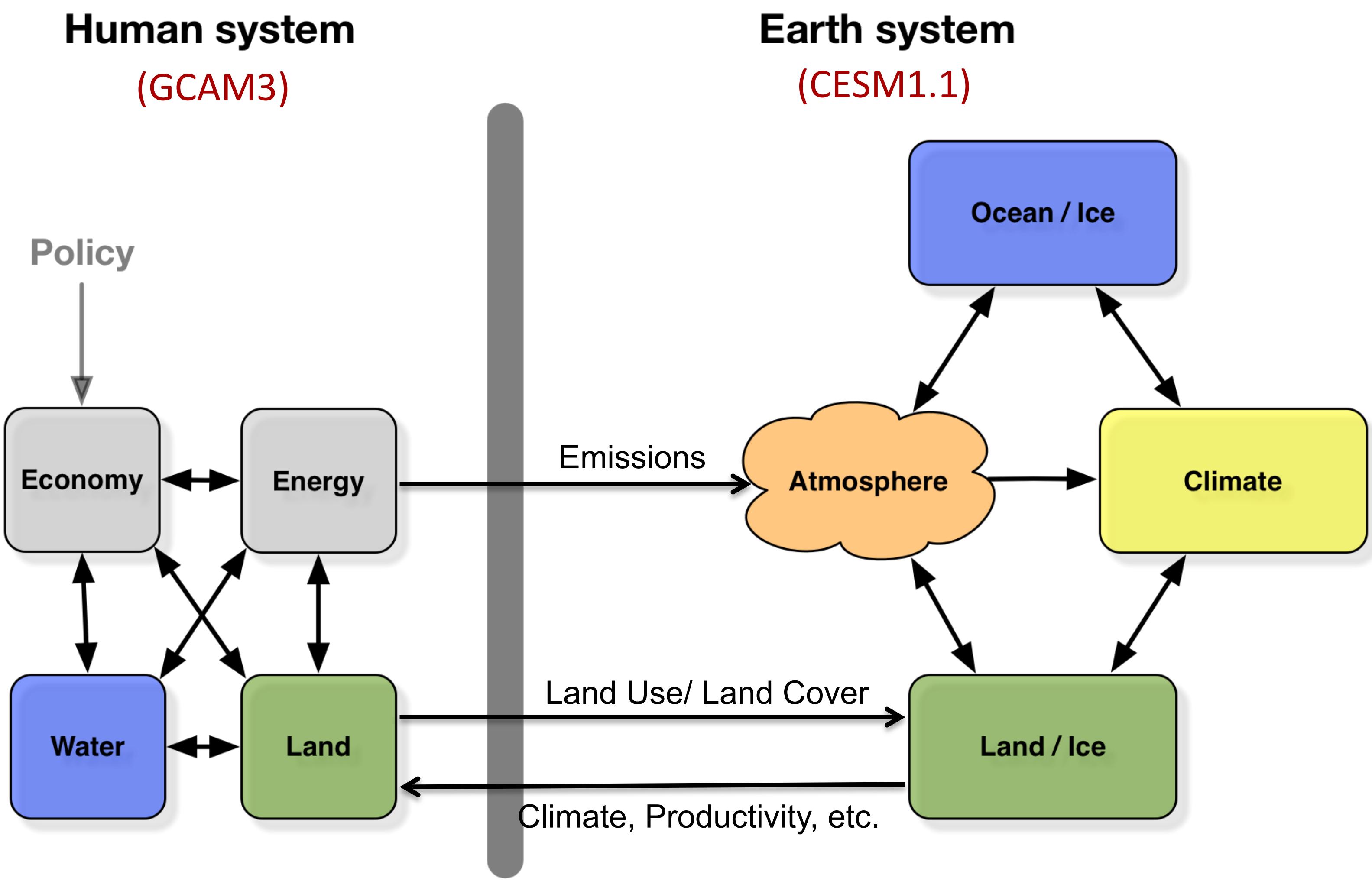
Multi-phase coupling of IAMs and ESMs / EMICs



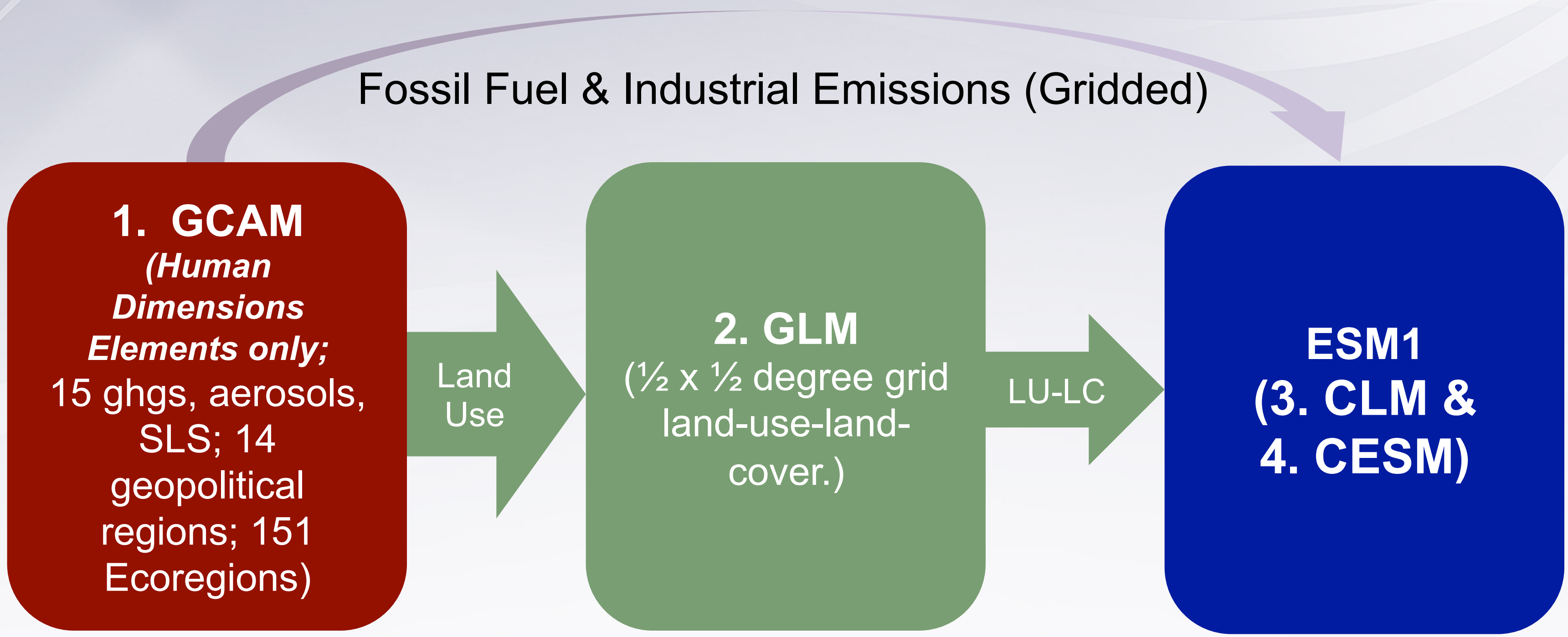
Feedback coupling of IAMs and ESMs / EMICs?



The integrated Earth System Model (iESM)

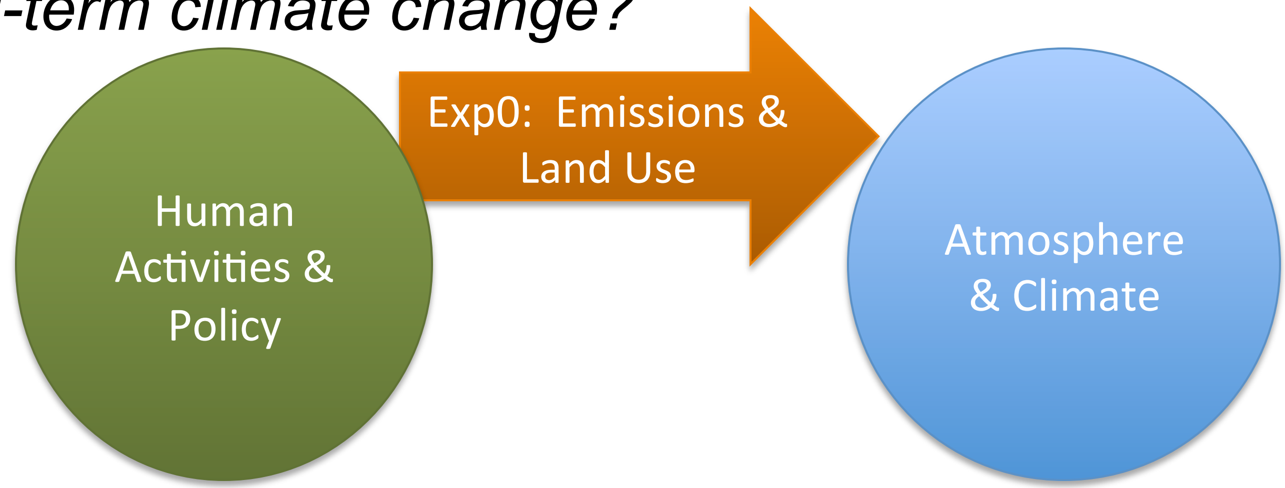


iESM links 4 models: GCAM, GLM, CLM, & CESM



Two major experiments

- **Experiment 0**: One-way coupling
- **Scientific Question:** *How much difference does land-use emissions mitigation policy make for near-term and long-term climate change?*



Three major experiments: Two complete

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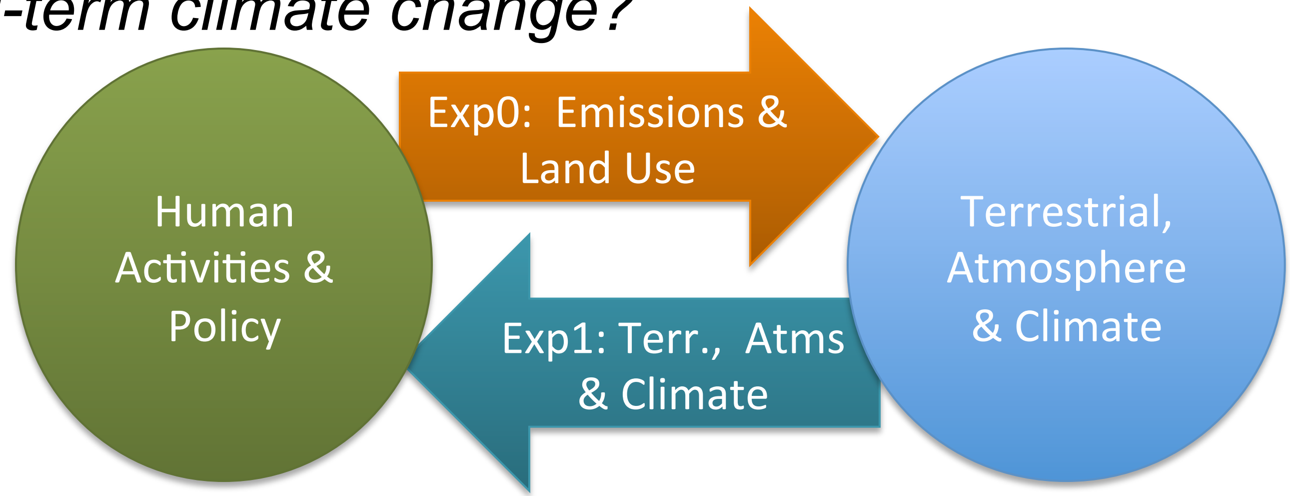
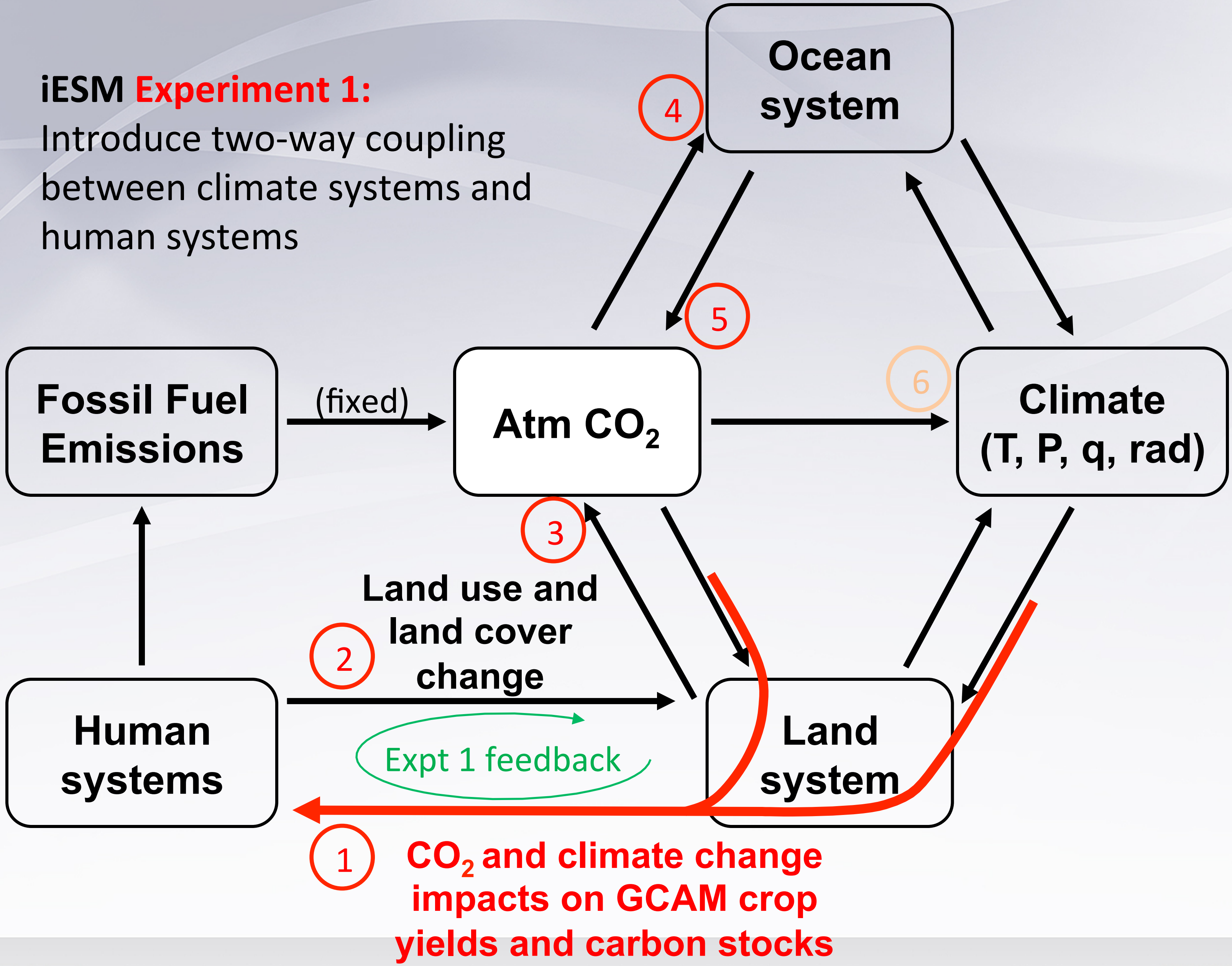
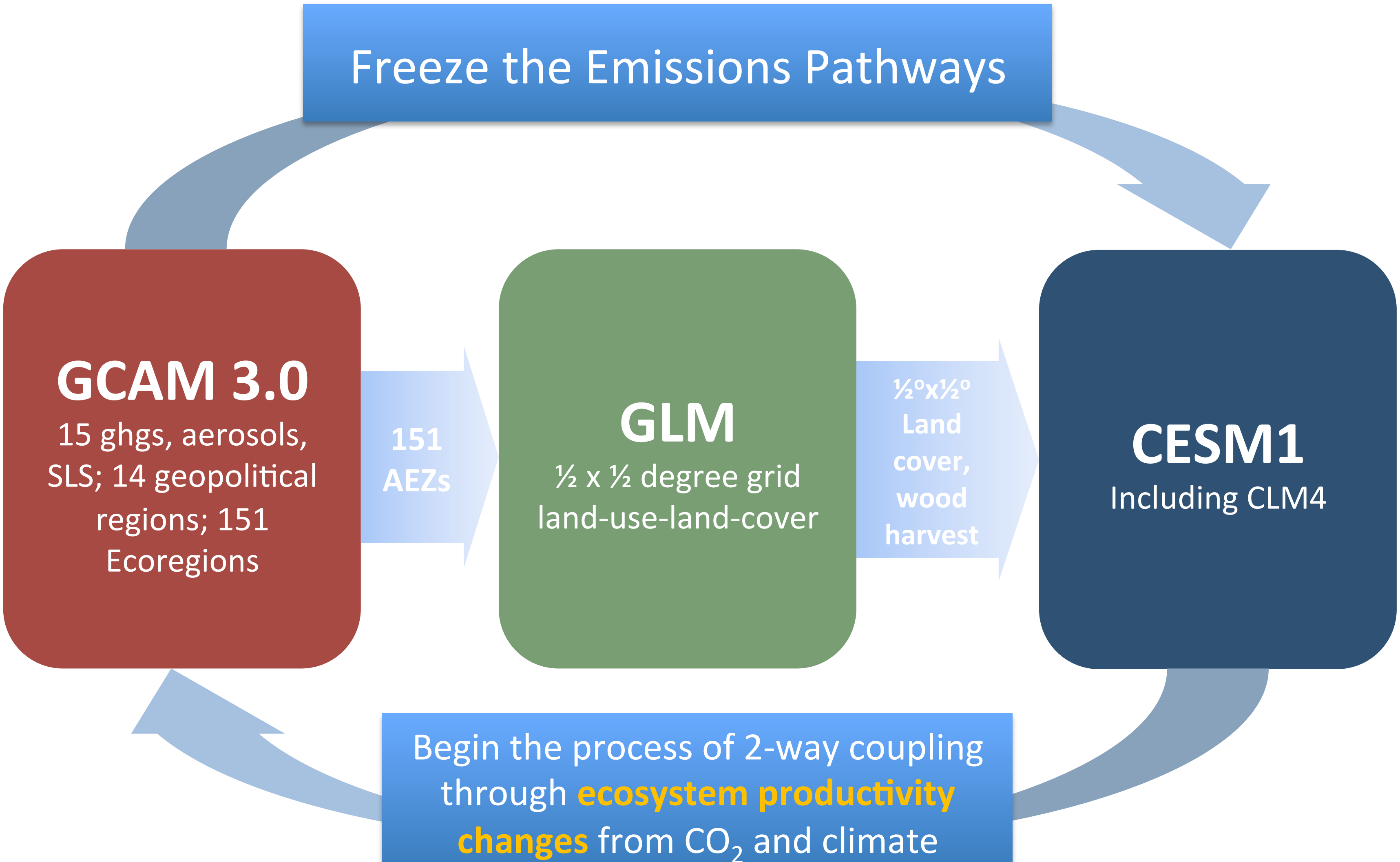


- **Experiment 1**: Two-way coupling of the land-use components
- **Scientific Question:** *How much difference does climate change make for crop yields and land use?*

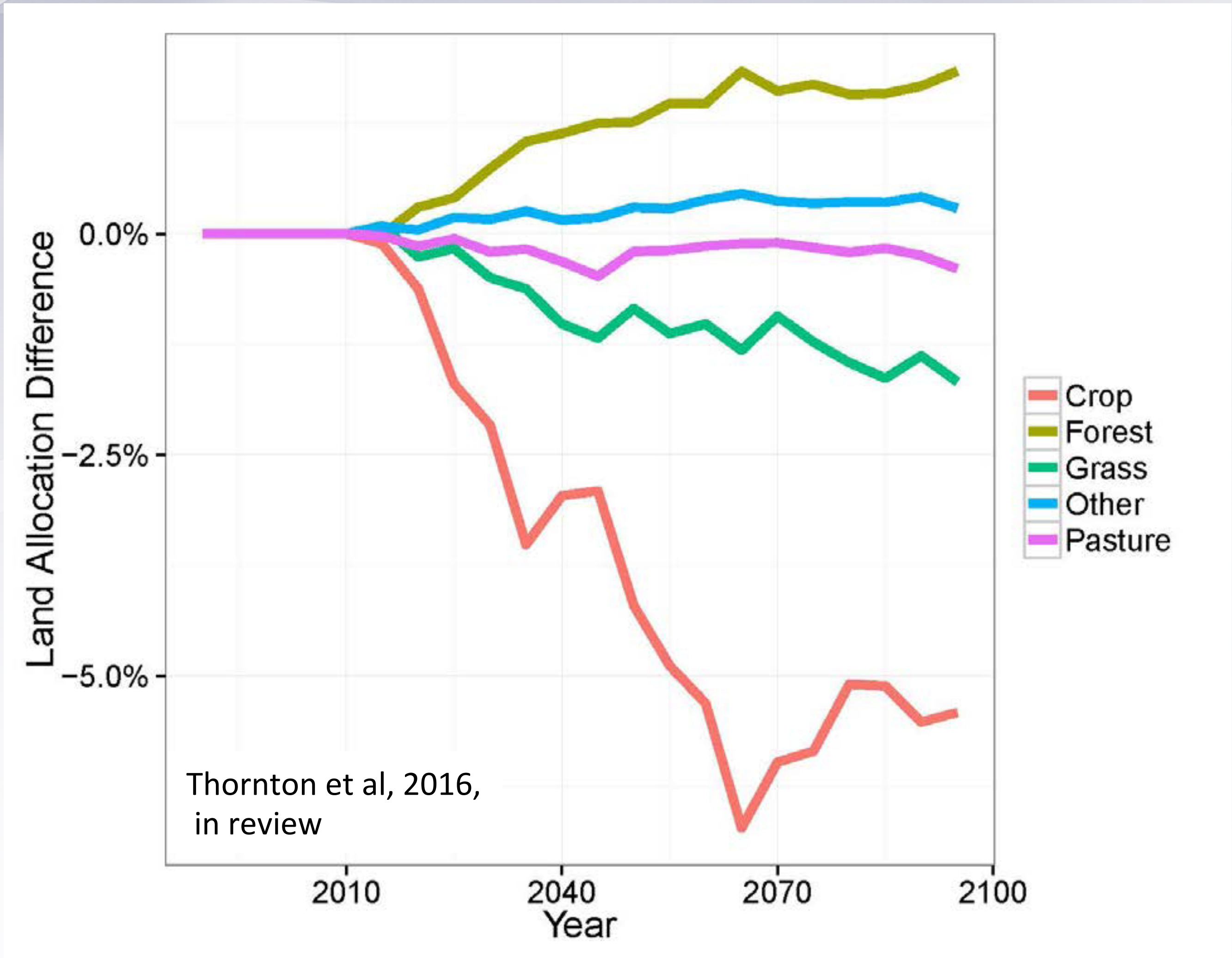
iESM Experiment 1:
Introduce two-way coupling between climate systems and human systems



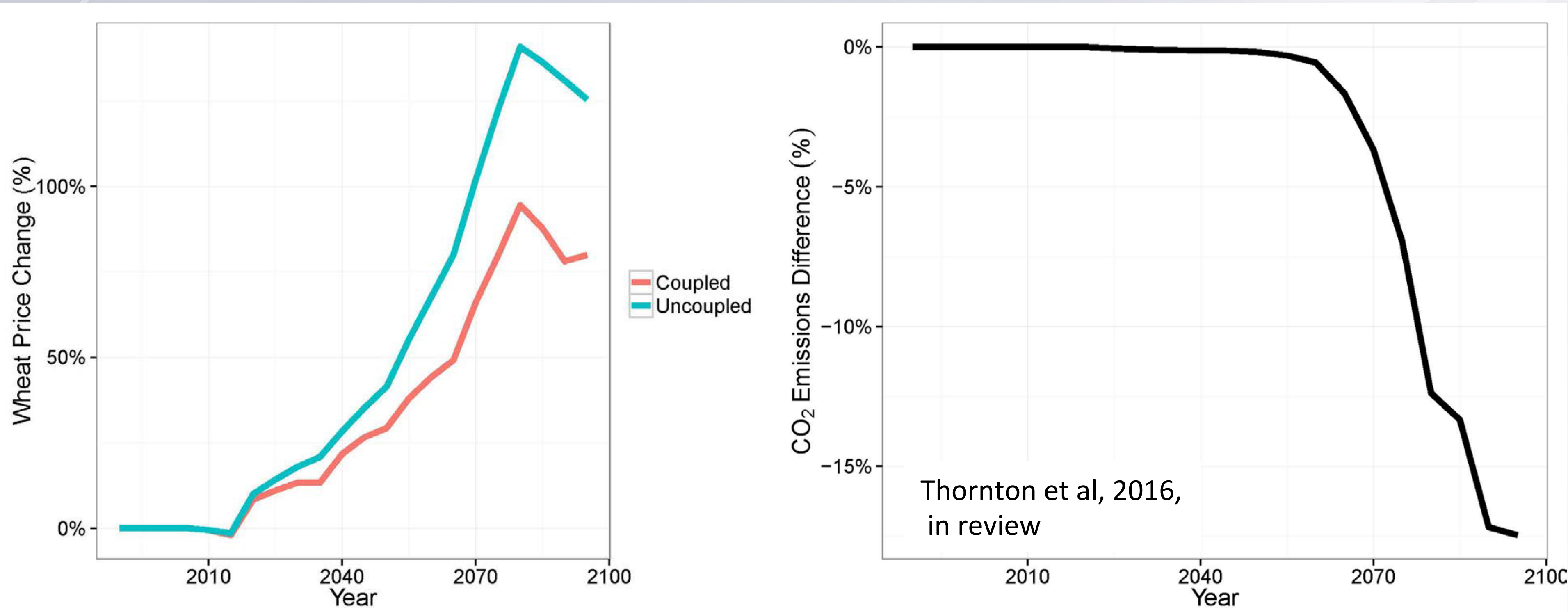
Design and Model Coupling in the iESM: Expt. 1



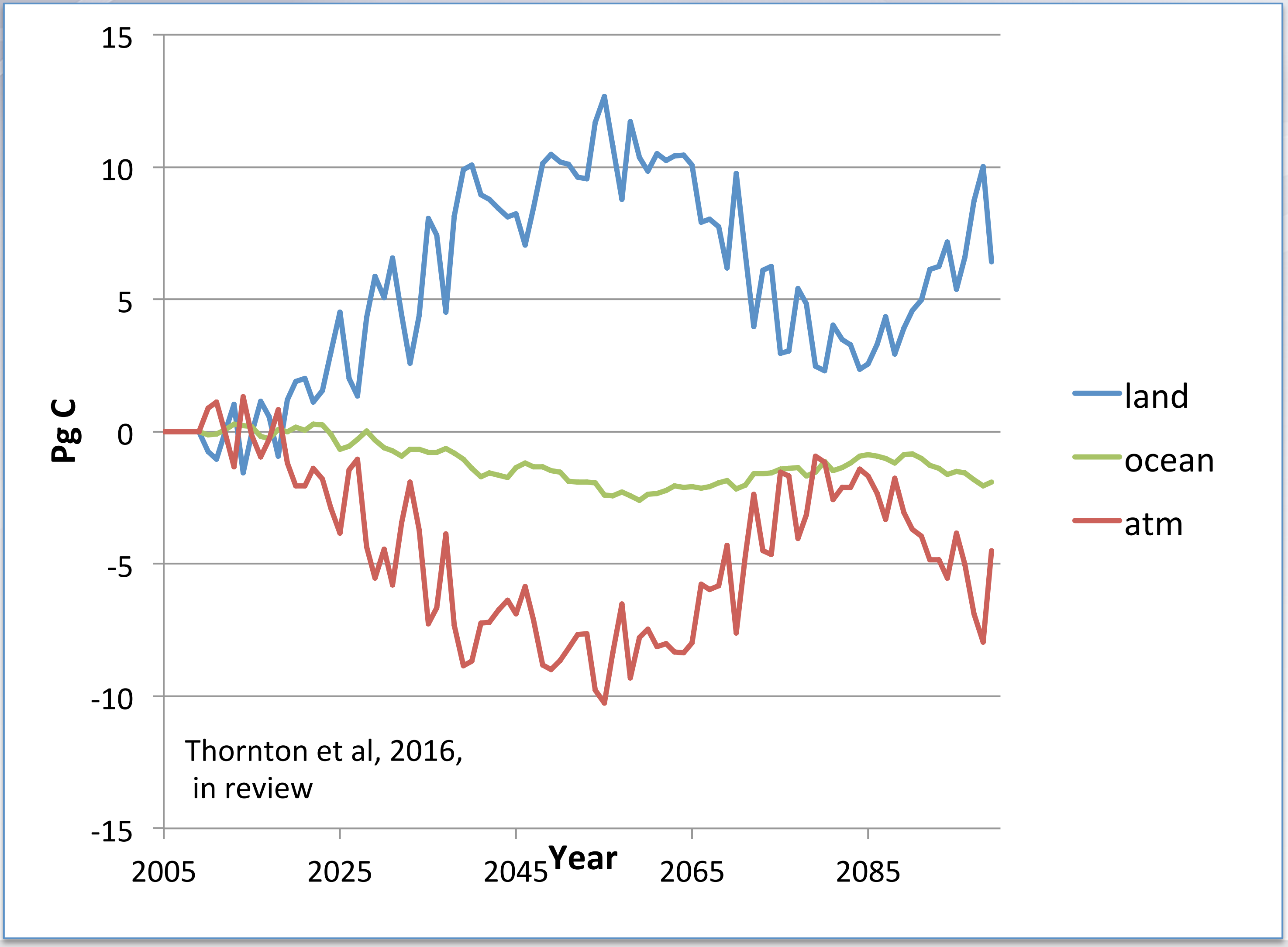
Experiment 1: Feedback changes land allocation



Experiment 1: Feedback alters commodity prices and fossil fuel emissions



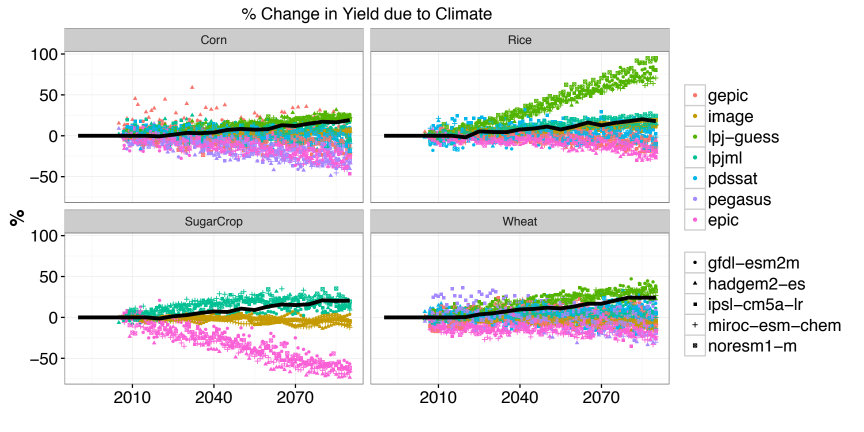
Experiment 1: Feedback alters global carbon cycle



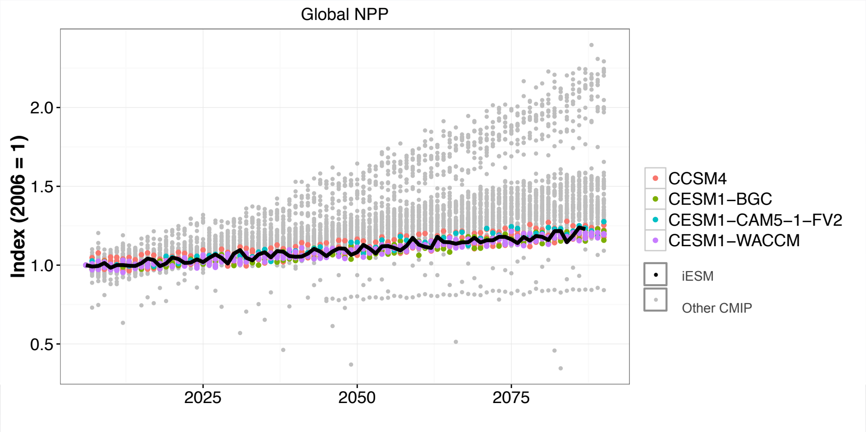
How robust is this signal across other models and approaches?

- Motivation:
  - We use a single climate and crop model, collapsing an important uncertainty.
- Approach:
  - Stand alone GCAM experiments using productivity change from CMIP5 and AgMIP
- Preliminary Findings:
  - We tend to have lower productivity growth than other climate models, but higher than other crop models.

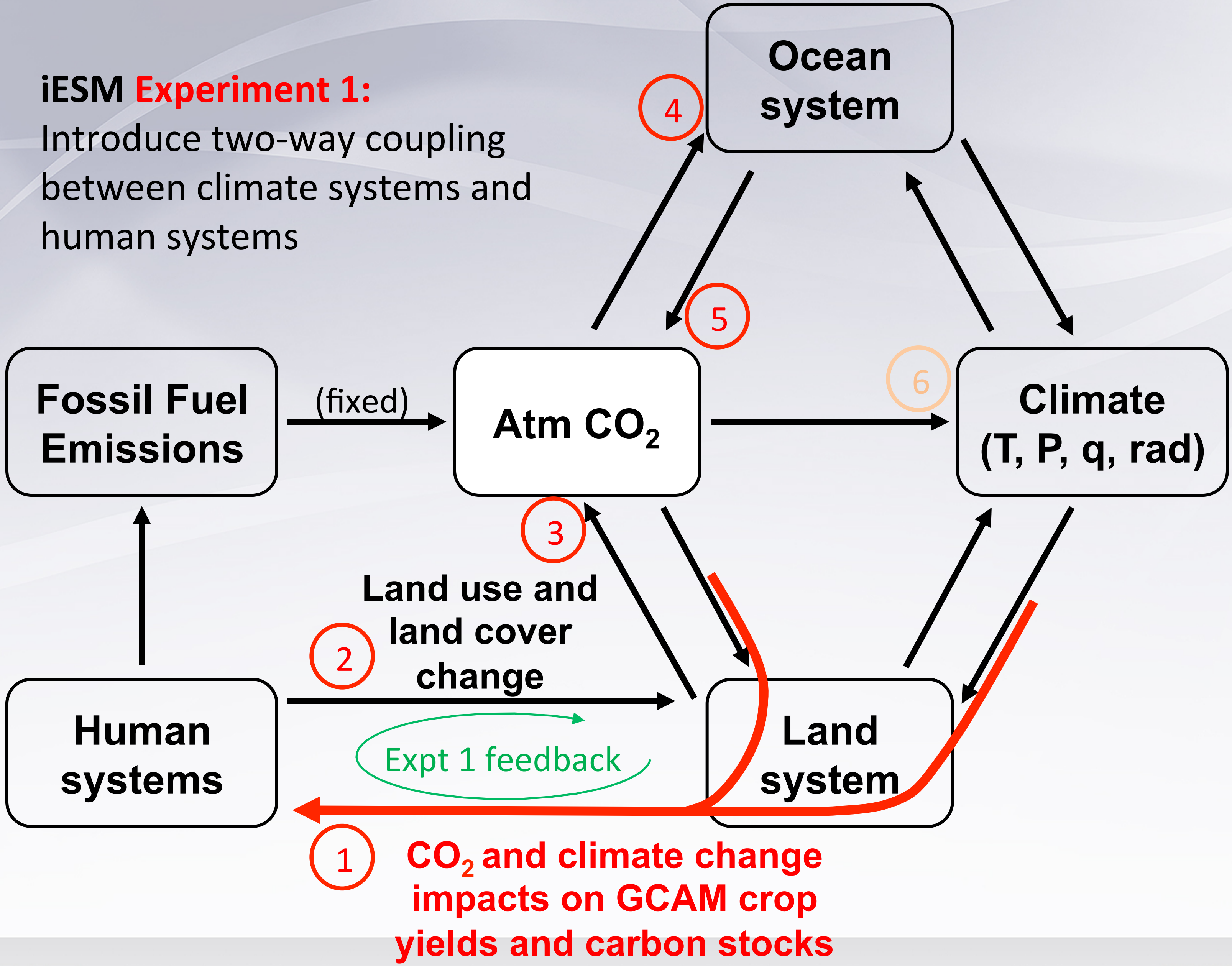
Comparison to AgMIP



Comparison to CMIP5



iESM Experiment 1:
Introduce two-way coupling between climate systems and human systems



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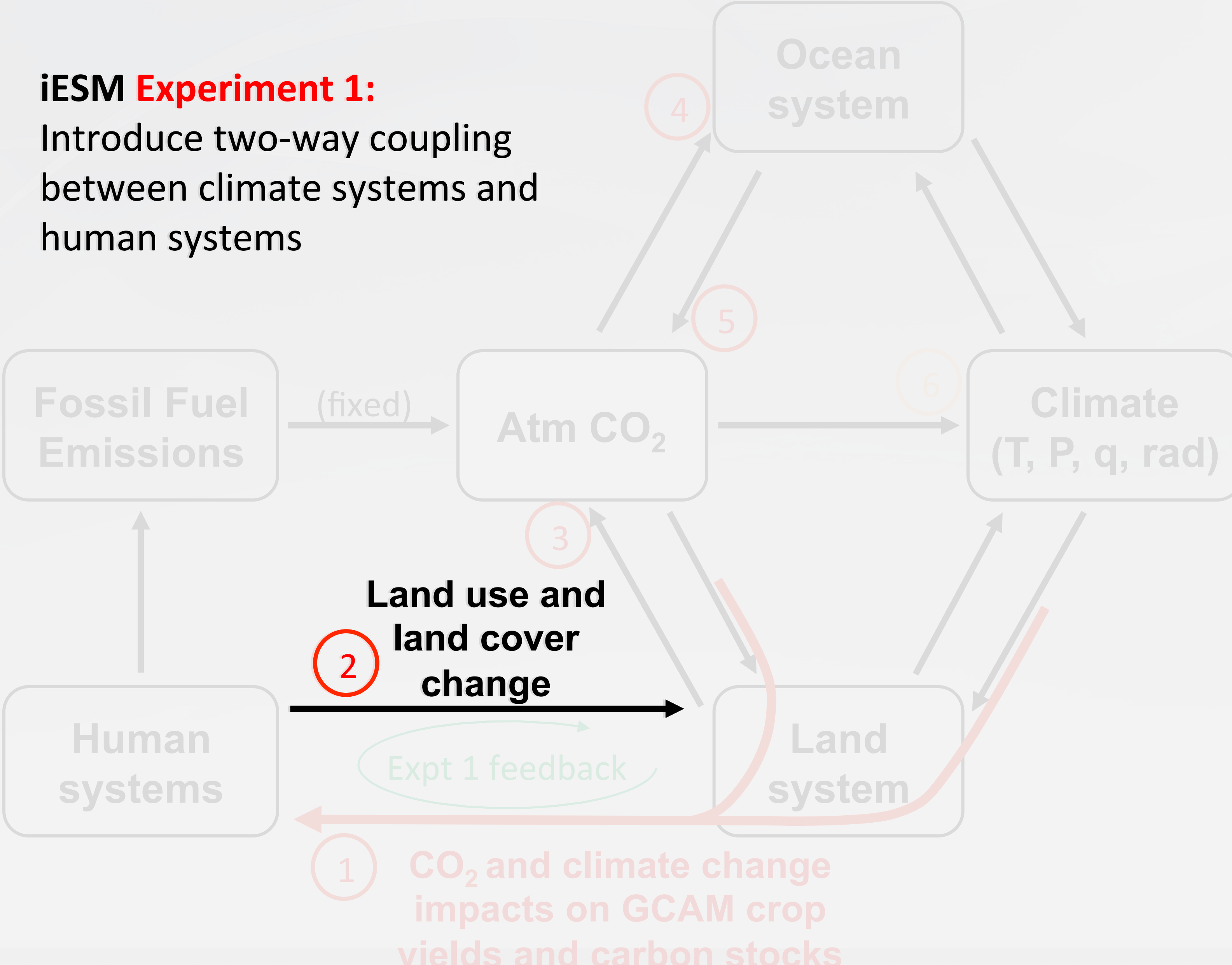

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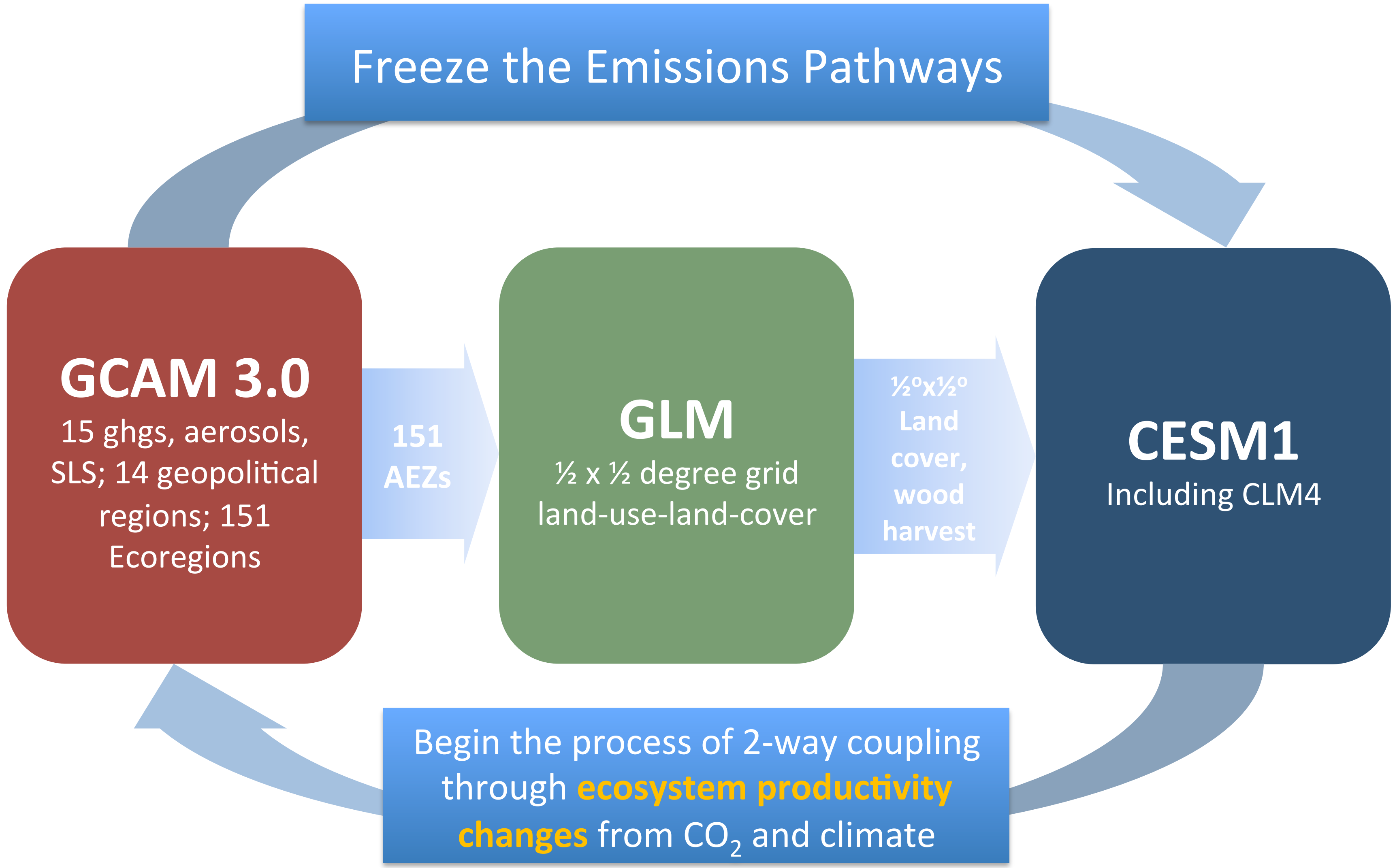

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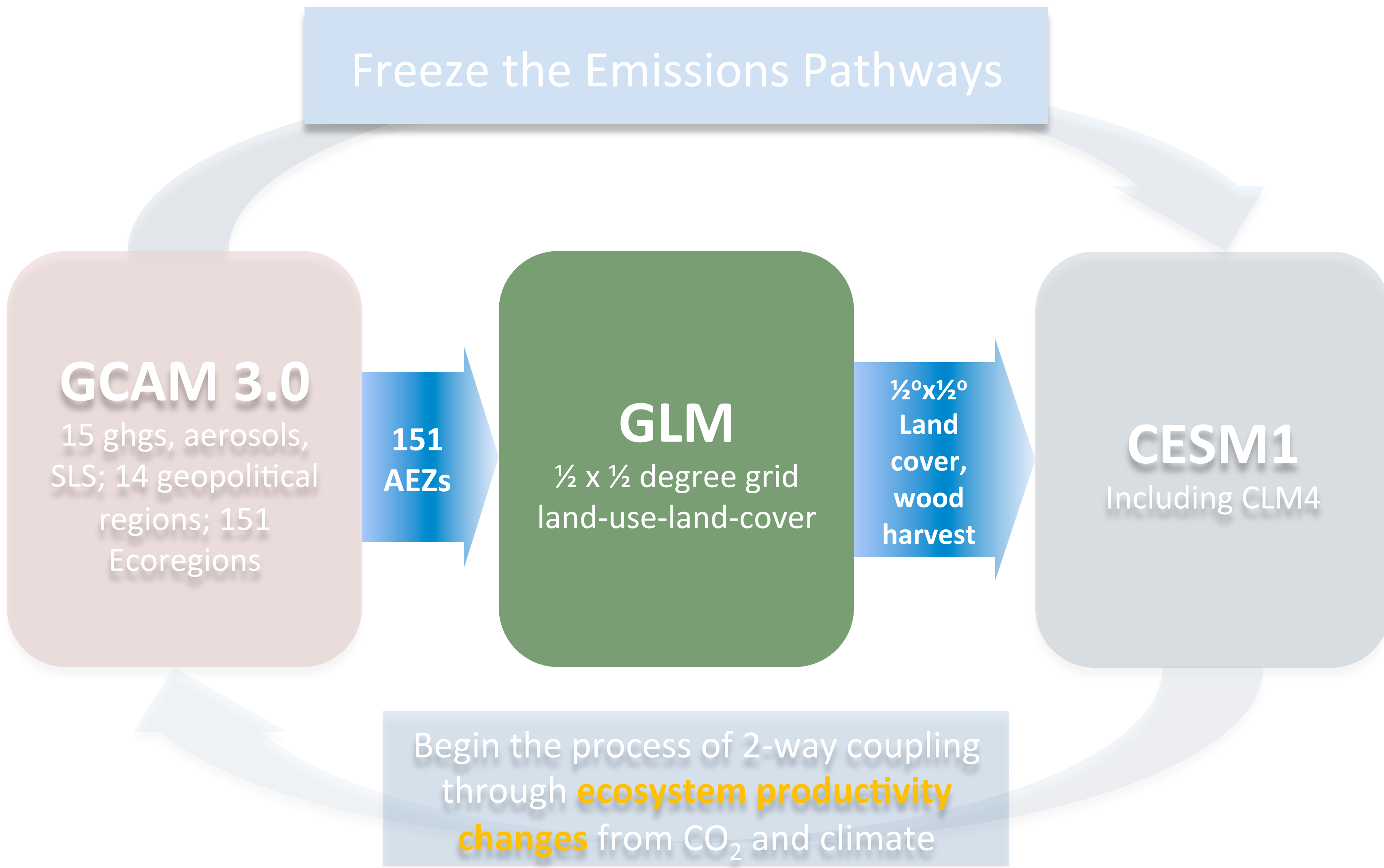
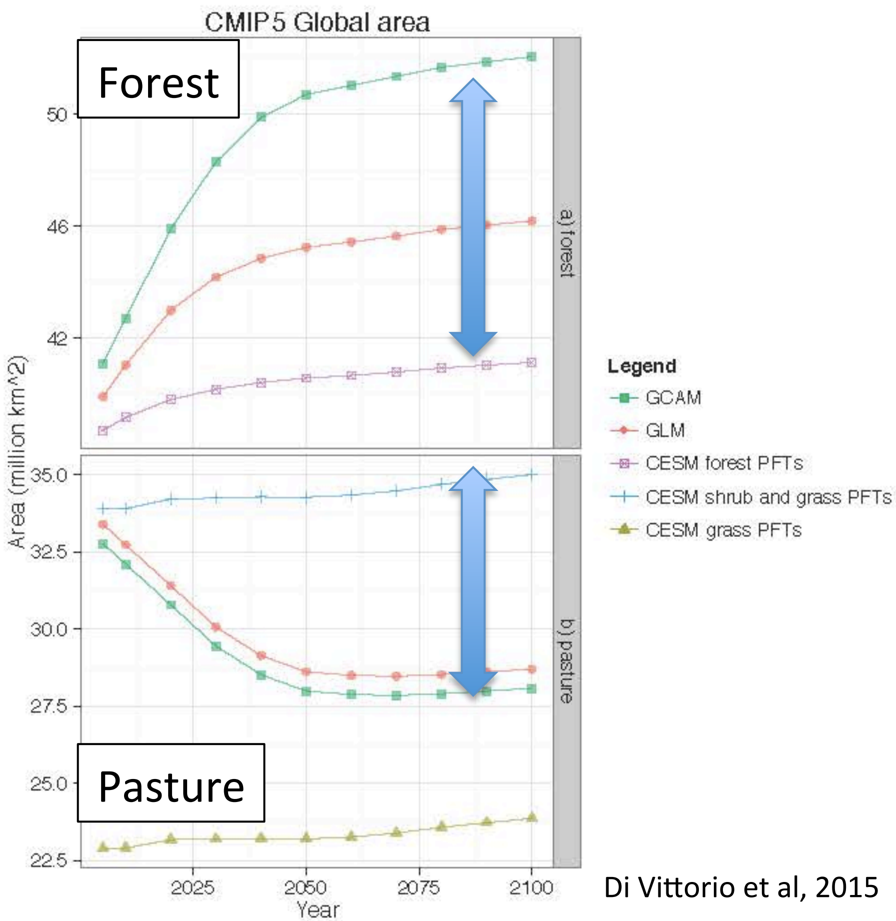


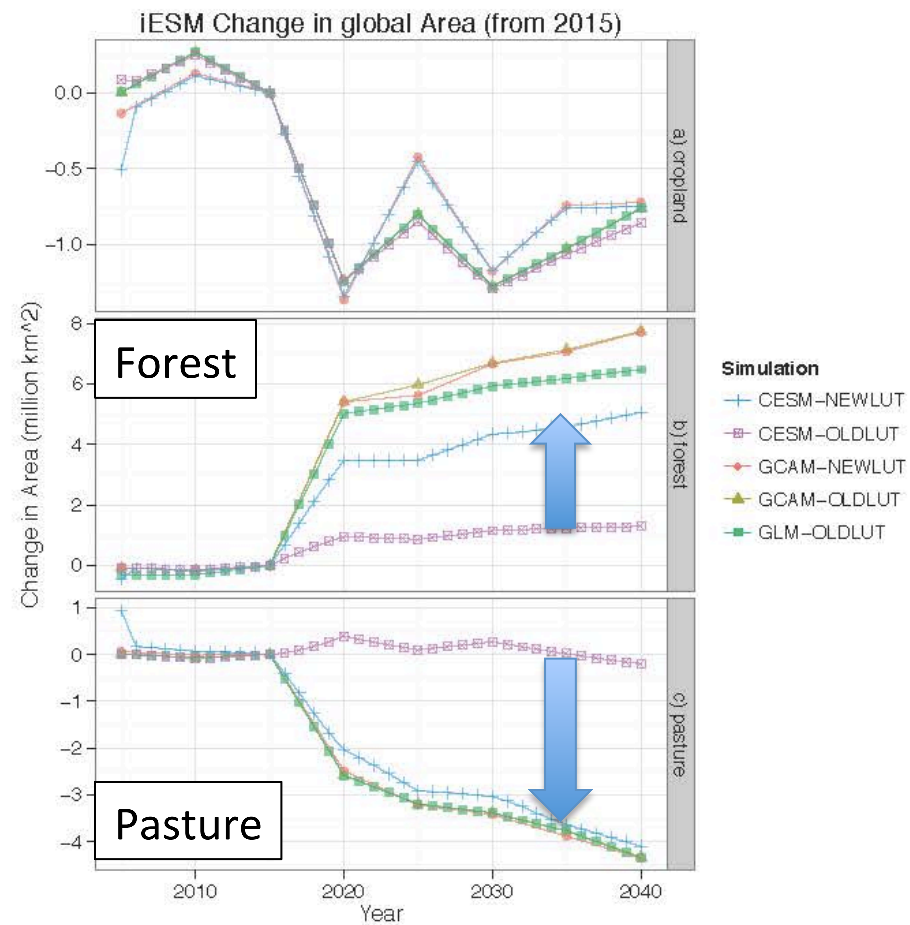
Issues in Translating LULCC from GCAM->CESM

The Problem

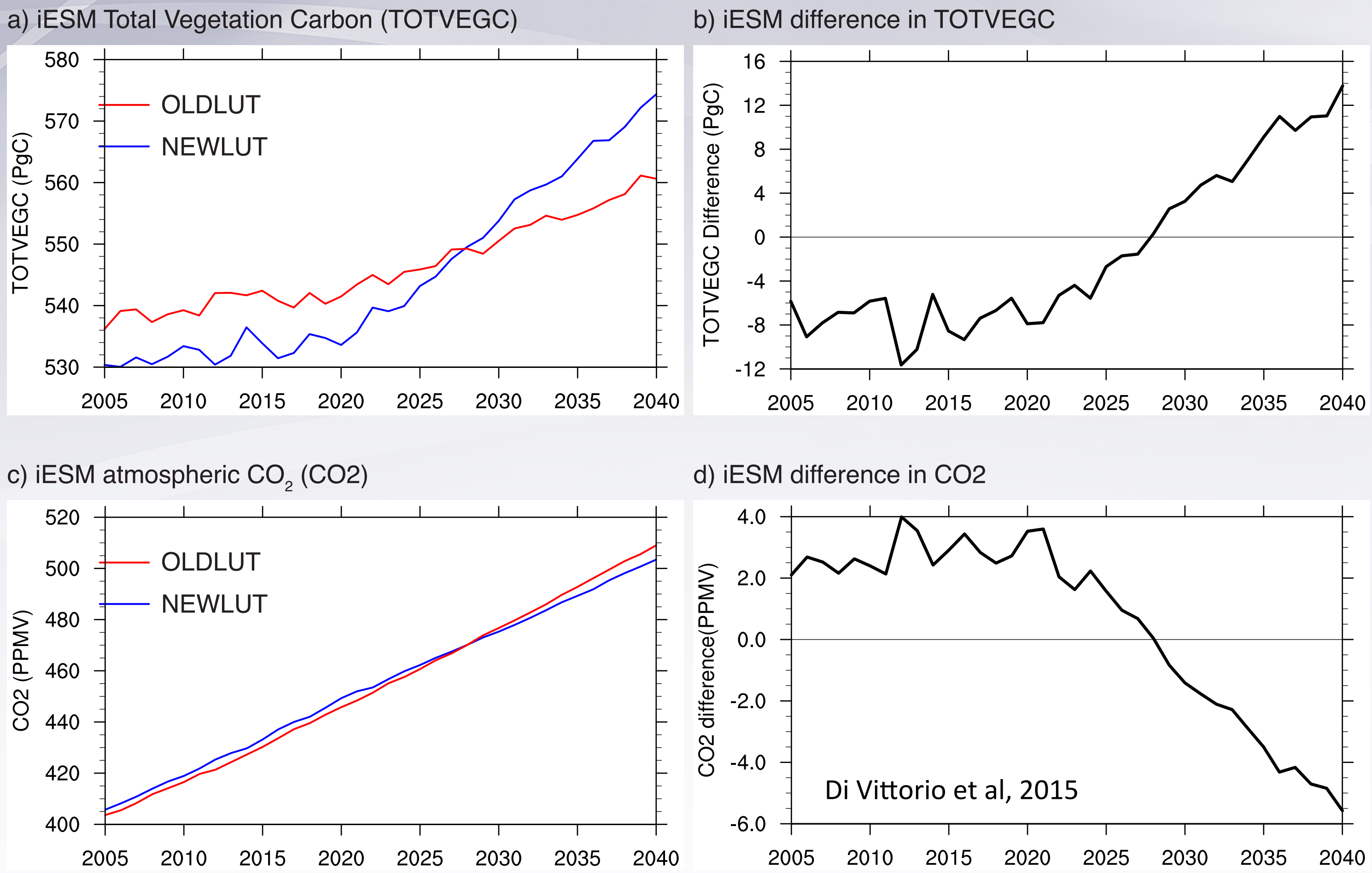


Di Vittorio et al, 2015

The Solution

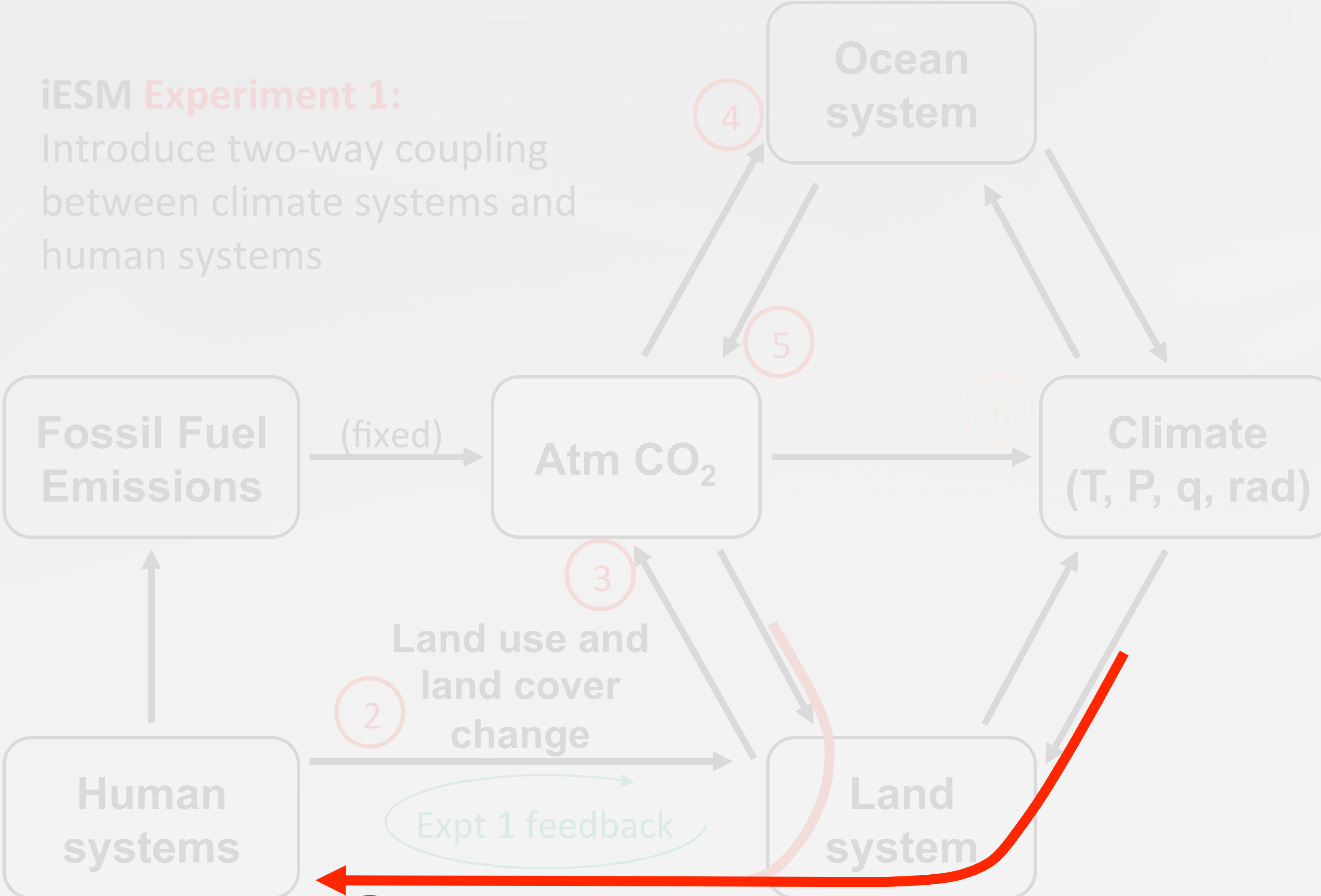


Impacts of Translating LULCC from GCAM->CESM



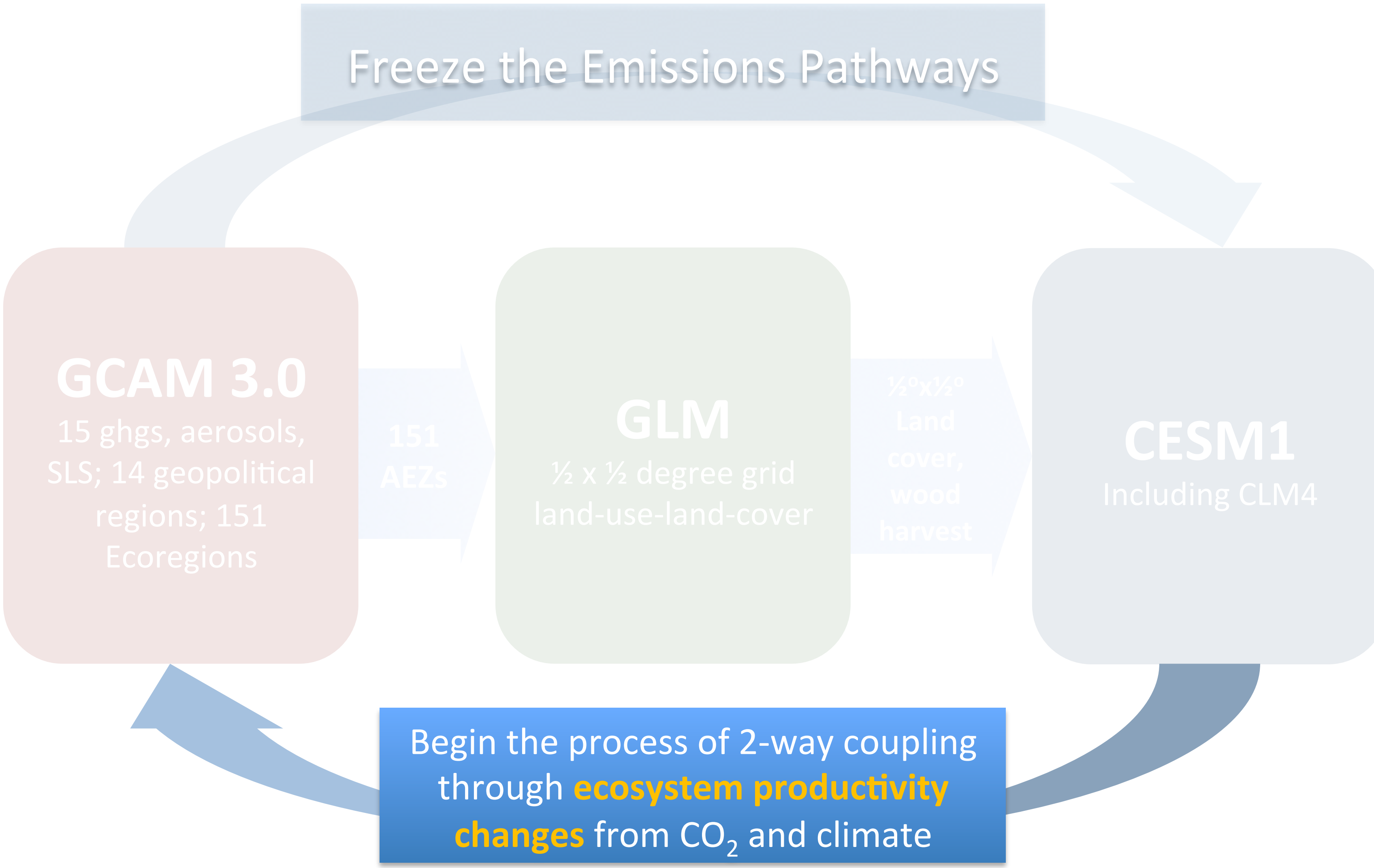
iESM **Experiment 1:**

Introduce two-way coupling between climate systems and human systems



1 **CO_2 and climate change impacts on GCAM crop yields and carbon stocks**

Design and Model Coupling in the iESM: Expt. 1

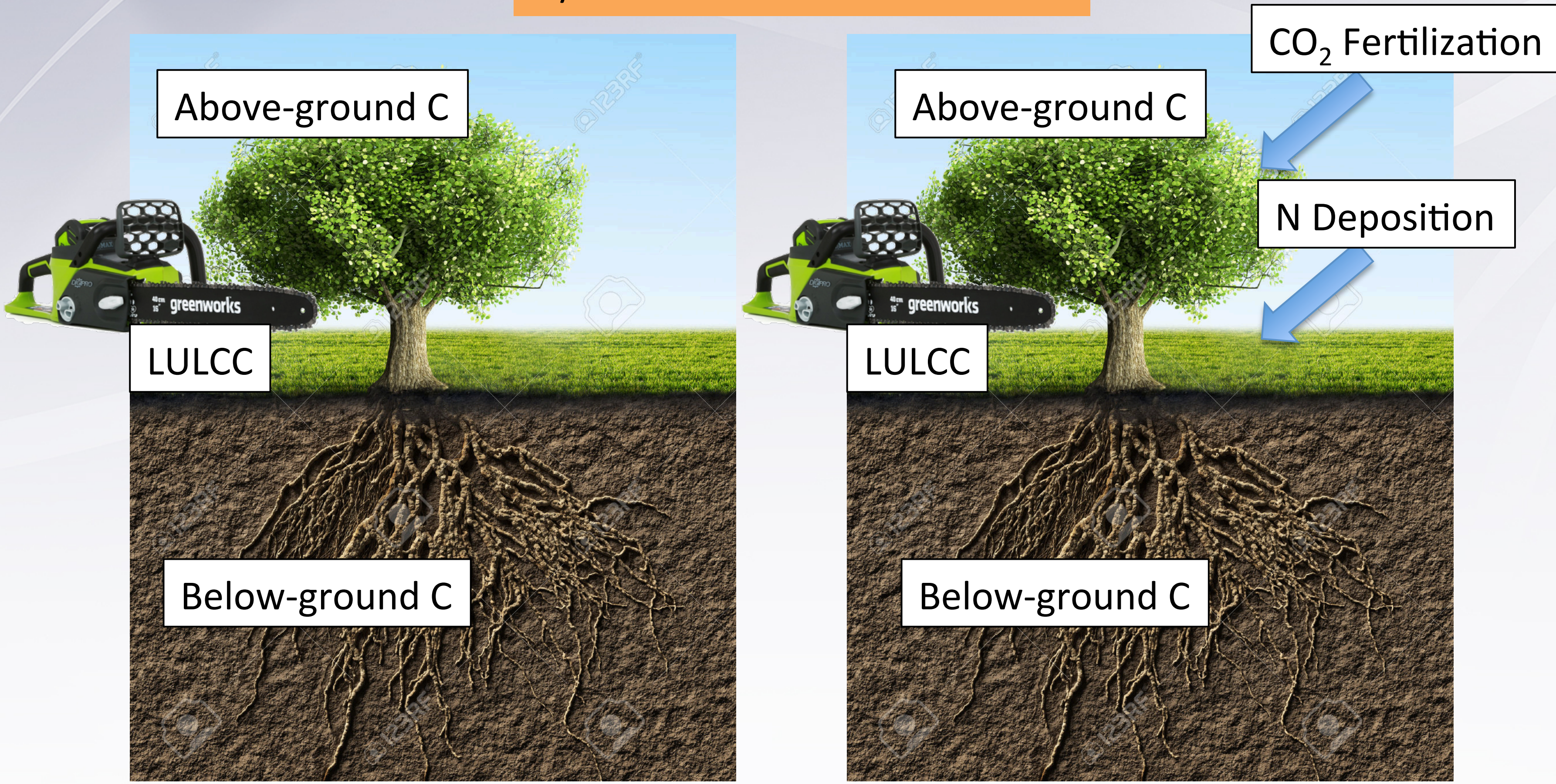


Translating Carbon Drivers from CESM->GCAM

GCAM

Need a proxy to convert CESM Drivers -> GCAM Biomass w/o effects of LULCC

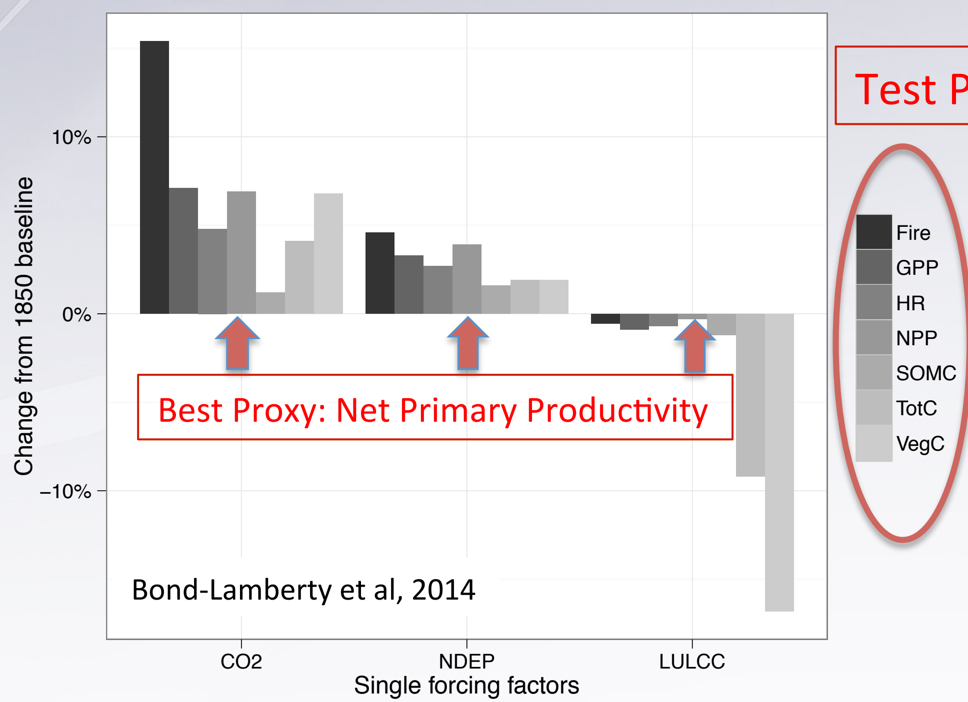
CESM



Translating Carbon Drivers from CESM->GCAM

CO_2 Fertilization | N Deposition | LULCC

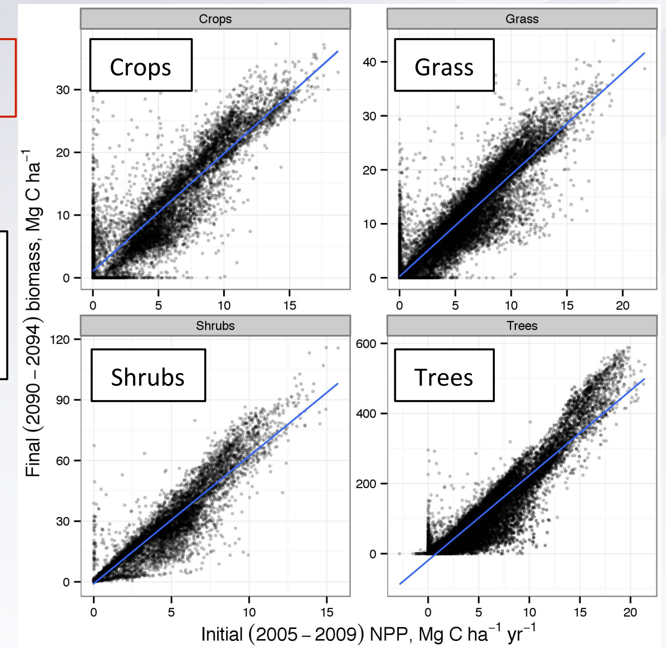
Test Proxies



Carbon Drivers

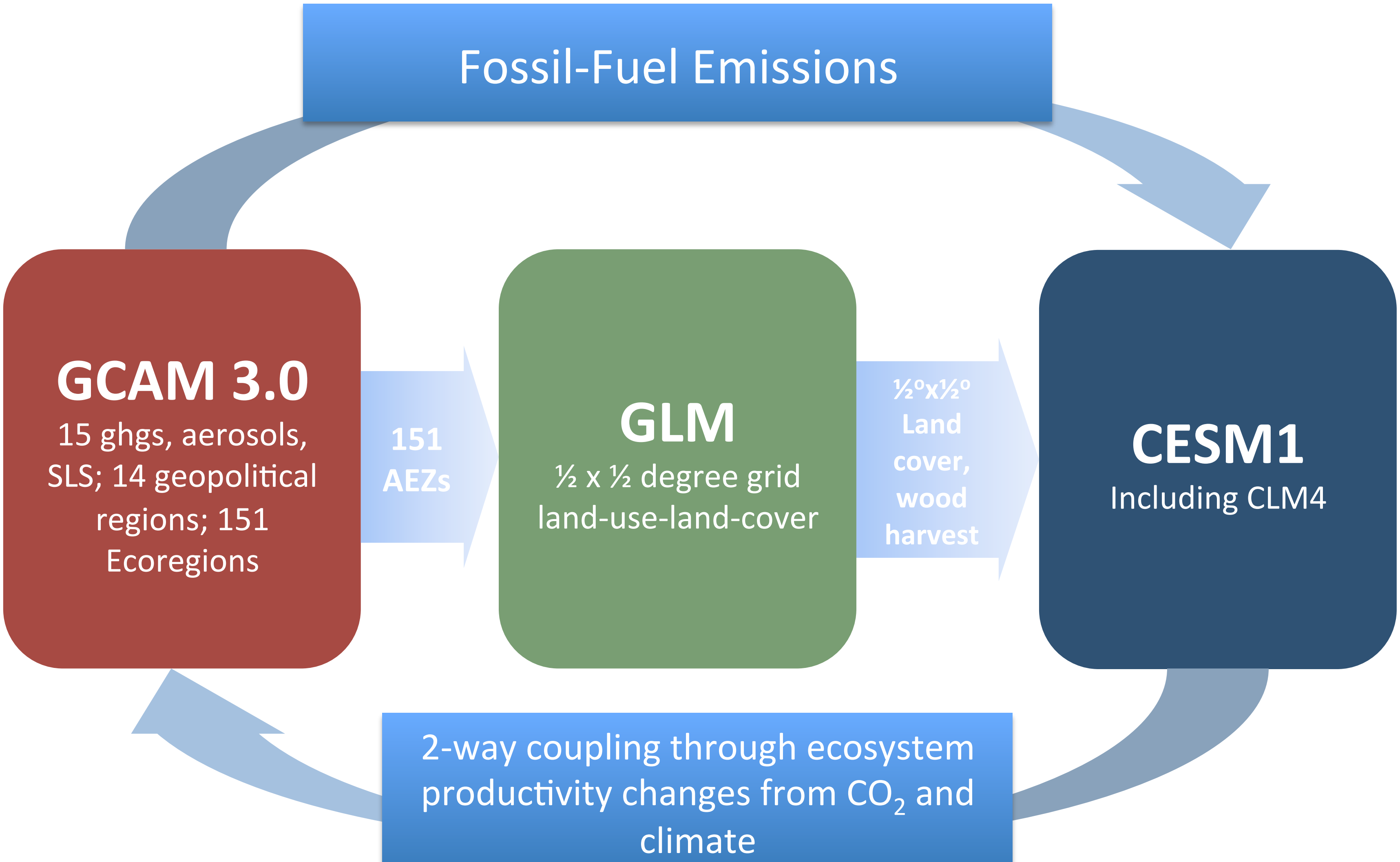
Proof of Principle

Biomass

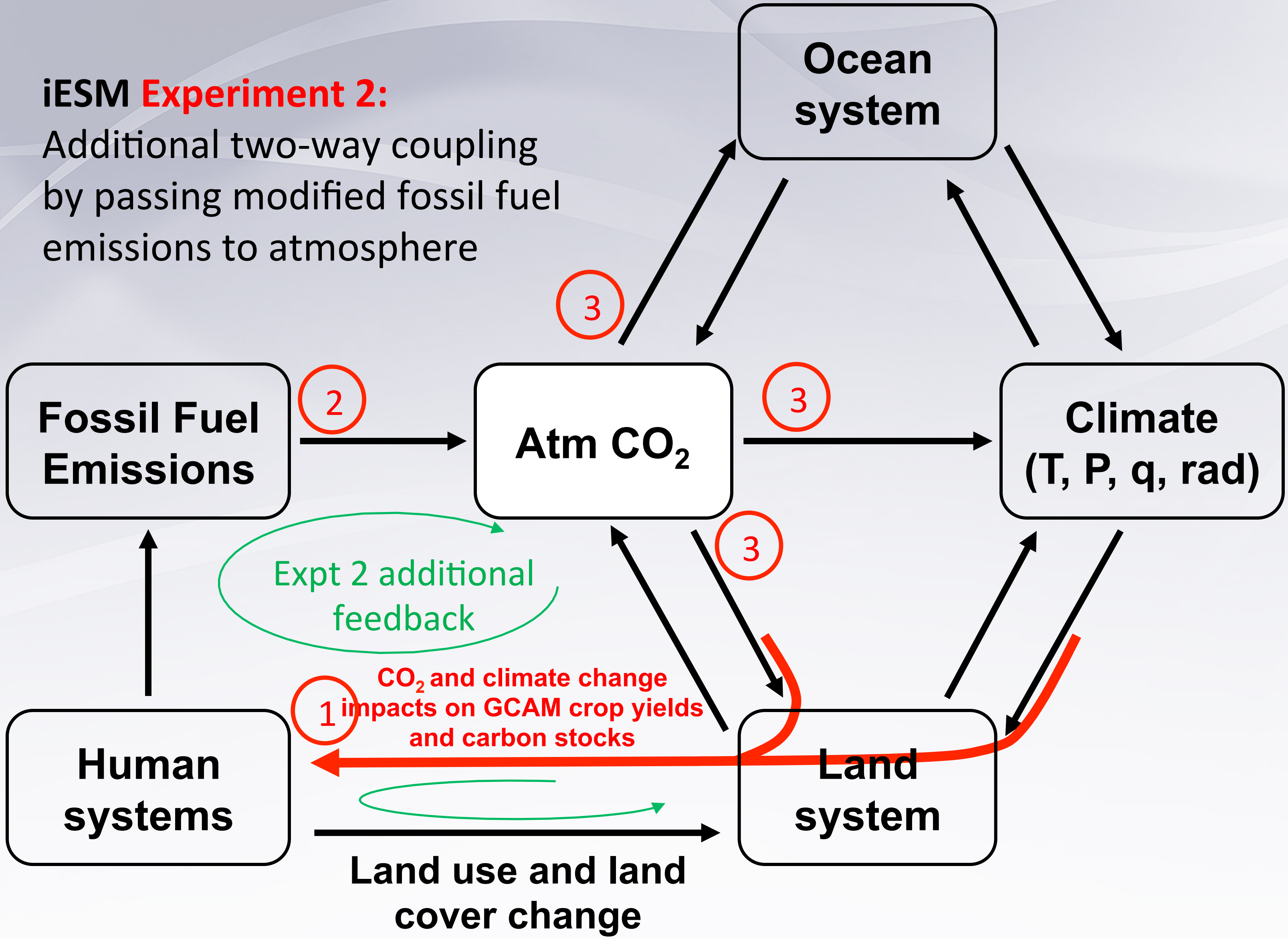


Net Primary Productivity

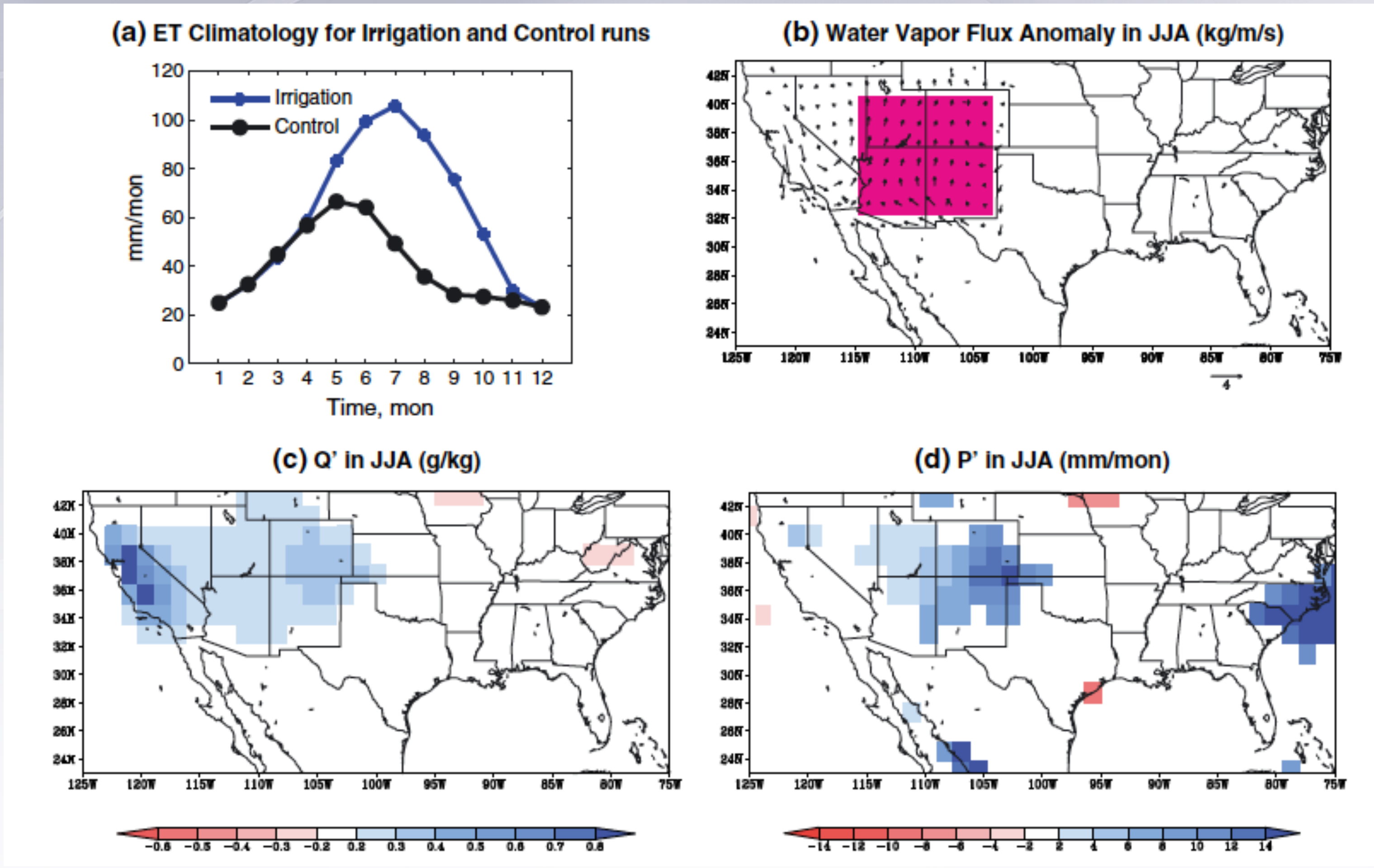
Design and Model Coupling in the iESM: Expt. 2



iESM Experiment 2:
Additional two-way coupling by passing modified fossil fuel emissions to atmosphere



Water: Motivation



- Irrigation in Central Valley has large influence on surface evapotranspiration with statistically significant remote effects on North American monsoon rainfall

(Lo et al. 2013 GRL)

Water: Preliminary Results

- Enhance representation of irrigation in ALM
  - Irrigation amount is calibrated against FAO census data
  - Both surface and groundwater irrigation source constrained by FAO census data
  - Different irrigation methods adopted

Sprinkler irrigation: water is applied uniformly as precipitation

Flood irrigation: water is applied to the root zone in 30 minutes

Drip irrigation: Water required is immediately transpired rather than added to the soil column

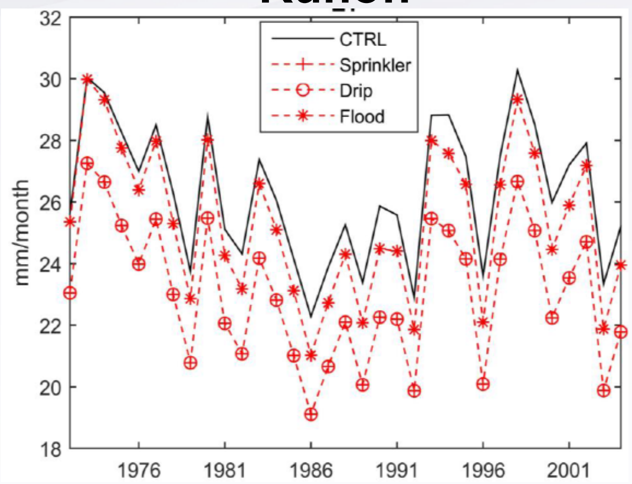
Water: Preliminary Results

- Numerical experiments with offline ALM

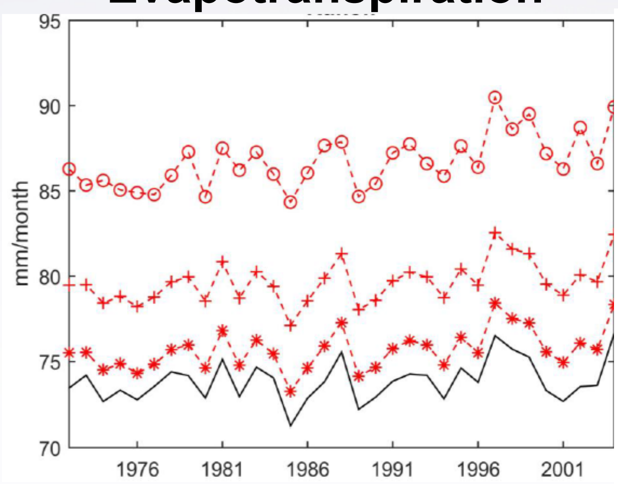
Name	Climate dataset [simulation period]	Irrigation	Calibrated	Pumping
CTRL	Qian Data (1972-2004)	no	---	---
IRRIG		yes	Yes	no
PUMP		yes	Yes	Yes
Drip		yes	Yes	Yes
Flood		yes	Yes	Yes
Sprinkler		yes	Yes	Yes

- Irrigation increases ET and reduces runoff and groundwater storage
- Irrigation effects on ET are largely dependent on the irrigation methods

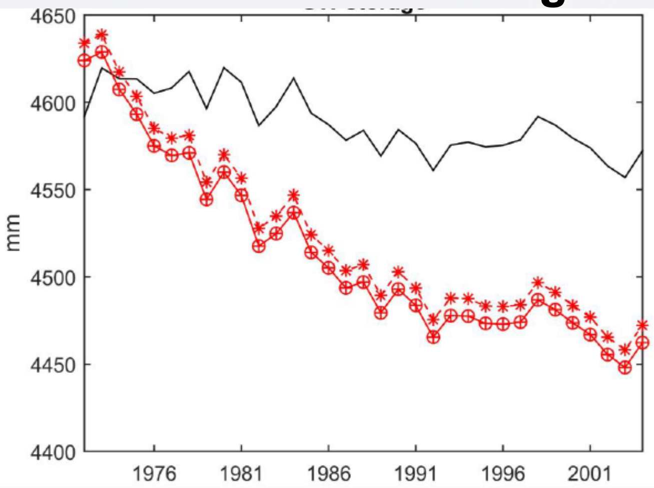
Runoff



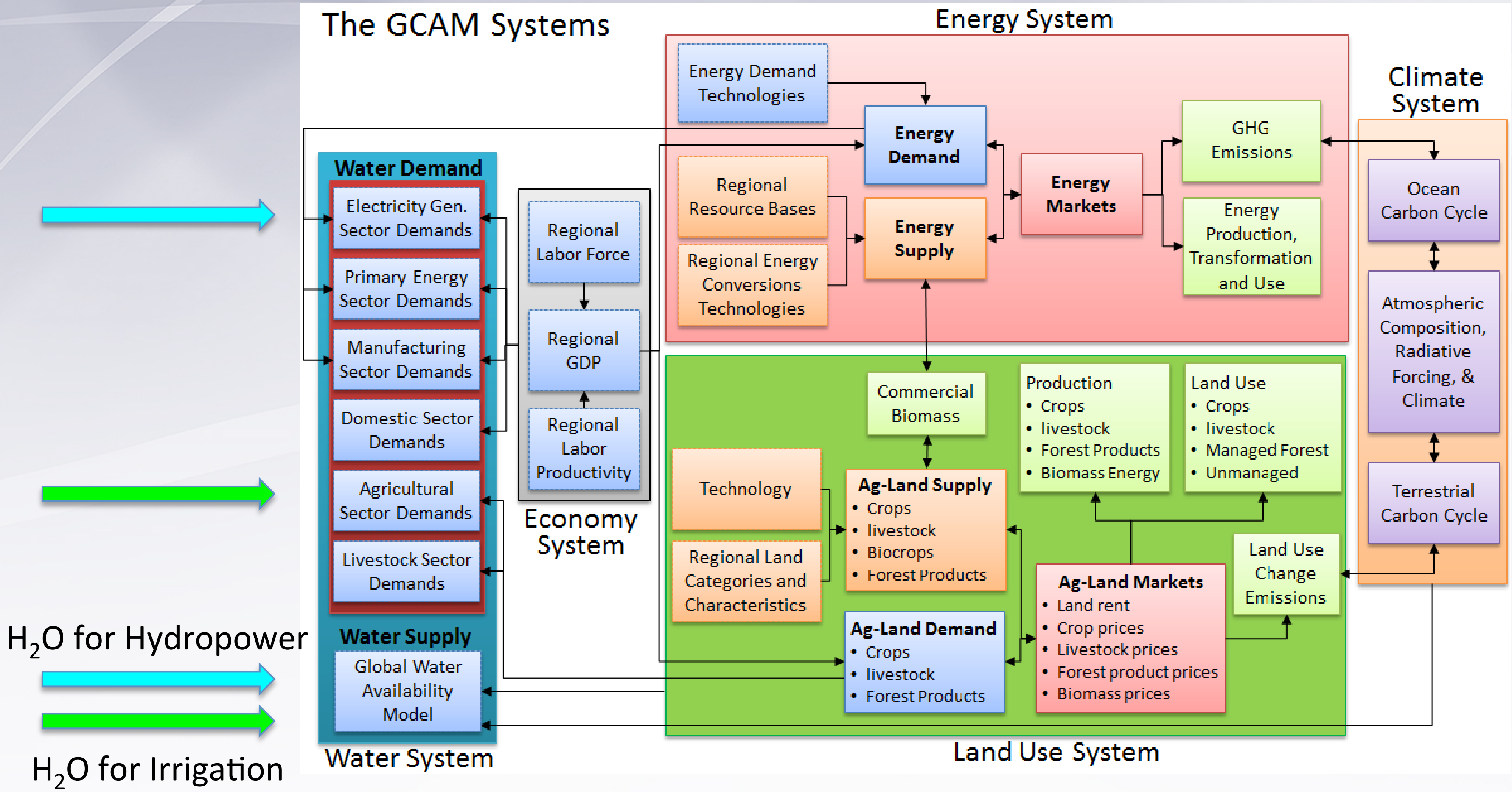
Evapotranspiration



Groundwater storage



Next: Coupling Climate to Water Cycle



Hejazi et al, 2014

Opportunities from further integration

- **Immediate** tests of climate impacts for future scenarios.
- Tool to enable “no regrets” scenario/path development.
- Advances in internally consistent treatment of water, energy, and climate in mitigation pathways.
- Quantification of impacts of feedbacks and interactions ***that are yet to be treated under current protocols and yet could be significant on mitigation timescales.***